

K_S^0 and Λ Production in Charged Particle Jets in p–Pb Collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE

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Abstract

We study the production of K_S^0 mesons and Λ baryons in jets in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with ALICE at the LHC. The p_T -differential density of the particles produced in jets is compared to the inclusive distributions and the Λ/K_S^0 ratio is reported in bins of multiplicity of the collisions. The hard scatterings are selected on an event-by-event basis using the anti- k_T clustering algorithm with resolution parameter $R = 0.2, 0.3$ and 0.4 , reconstructed from charged particles with a minimum $p_{T,jet}$ of 10 (or 20) GeV/ c .

Keywords: p–Pb collisions, particle production, jet fragmentation, baryon anomaly

1. Introduction

The strong suppression of high p_T charged particles [1, 2] and jets [3] measured in heavy-ion collisions at the LHC is not present in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [4]. However, the “double-ridge” structure observed in the long-range two-particle correlations in high multiplicity p–Pb collisions [5, 6] resembles collective features found in Pb–Pb collisions [7]. It has been suggested that some final state effects, such as parton-induced interactions [8] and strong correlations in particle production characteristic of a high density system [9, 10] may be present in p–Pb collisions. In addition, an enhancement of the baryon-to-meson yield ratio at intermediate $p_T \sim 3$ GeV/ c in high multiplicity p–Pb collisions as compared to pp collisions [11] has been observed. This effect is qualitatively similar to the enhancement observed in Pb–Pb collisions [12] that has been discussed in terms of collective flow [13], which could be presented in small systems like pp collisions [14], and/or parton recombination [15]. To discriminate between hard and soft processes contributing to the baryon and meson production, we study the Λ/K_S^0 ratio within jets and compare it to inclusive distributions measured in p–Pb and minimum-bias simulations generated by PYTHIA8 (tune 4C) [16] for pp collisions at $\sqrt{s} = 5.02$ TeV.

2. Experimental Setup and Analysis Strategy

This analysis is performed for minimum bias p–Pb events at $\sqrt{s_{NN}} = 5.02$ TeV, corresponding to integrated luminosity of $\mathcal{L}_{int} = 51 \mu\text{b}$. For a detailed description of the ALICE detector and its performance, see [17, 18]. The event multiplicity classes are determined by the VZERO-A detector (V0A) covering pseudorapidity of $2.8 < \eta < 5.1$

¹A list of members of the ALICE Collaboration and acknowledgements can be found at the end of this issue.

in the Pb-going direction. The uncertainty of multiplicity estimation is made using energy deposition in the Pb-going side Zero Degree Calorimeter (ZNA) and determined by the so-called *hybrid method* [19].

Charged particles are measured using the Inner Tracking System (ITS) and the Time Projection Chamber (TPC). The ITS also provides measurement of the primary vertex. The selection of tracks used for the jet reconstruction (see [20] for details) ensures an almost uniform tracking efficiency in full azimuth. Tracks with $p_T > 150$ MeV/c are retained in the analysis. Charged particle jets are reconstructed with the anti- k_T algorithm [21], with resolution parameter $R = 0.2, 0.3$ and 0.4 . To remove combinatorial jets a cut on the jet area A_{jet} [22] is applied and only jets with $A_{\text{jet}} > 0.6\pi R^2$ are retained. The reconstructed jet p_T is obtained by subtracting the energy of the underlying background according to the approach introduced in [22]: $p_{T,\text{jet}}^{\text{ch}} = p_{T,\text{jet}}^{\text{det}} - \rho \times A_{\text{jet}}$, where $p_{T,\text{jet}}^{\text{det}}$ is the measured jet p_T , and ρ is the underlying background density obtained with the median occupancy method [23]. The analysis is performed separately for two selections of jets: with $p_{T,\text{jet}}^{\text{ch}} > 10$ GeV/c and with $p_{T,\text{jet}}^{\text{ch}} > 20$ GeV/c. A fiducial cut was applied requiring the jet centroid to be within the detector acceptance $|\eta_{\text{jet}}| < 0.75 - R$.

The Λ and K_S^0 (V^0 s) are reconstructed via the hadronic decays, $\Lambda \rightarrow p\pi^-$ and $K_S^0 \rightarrow \pi^+\pi^-$. Decay daughters are identified by their specific ionization, dE/dx , in the TPC. The yield of V^0 signal is extracted using an invariant mass analysis with the bin counting method [24]. Tracks used for jet reconstruction are required to point to the primary vertex. Since this selection removes tracks from secondary weak decays, the V^0 reconstruction is performed independently of the jet reconstruction. To obtain the yield of V^0 particles associated with jets, each V^0 particle is matched with a jet if the distance within the $(\eta - \varphi)$ plane between the particle and the jet axis, $R(V^0, \text{jet})$ is smaller than the resolution parameter R : $R(V^0, \text{jet}) < R$. In addition, V^0 particles were required to fulfill a fiducial cut of $|\eta_{V^0}| < 0.75$.

The V^0 particles not associated to a hard scattering are selected using two criteria:

- *outside cone* (OC V^0): the V^0 particles reconstructed outside the jet cone of any of the reconstructed jets in the event, *i. e.* $R(V^0, \text{jet}) > R_{\text{cut}}$, where $R_{\text{cut}} = 0.4, 0.6$ and 0.8 ;
- *non-jet events* (NJ V^0): V^0 particles found in events without any jet having $p_T > 5$ GeV/c.

The uncertainty on the contribution of background V^0 particles to the jet signal is given by the difference between the spectra of NJ V^0 s and OC V^0 s with various R_{cut} values.

The reconstruction efficiency of the V^0 particles was obtained (separately for K_S^0 and Λ) by a detector-level simulations incorporating a realistic detector description, using the GEANT3 package. Since the efficiency of the V^0 depends on pseudorapidity and is sensitive to the η dependent distribution of jets, the efficiency obtained from simulations was weighted with the jet distribution obtained in the data.

The per event p_T -differential density $d\rho/dp_T$ of V^0 particles is given by the corrected p_T spectrum, dN/dp_T scaled by the area of the acceptance given either by the jet area or the acceptance not associated to the jet production (OC or NJ selection):

$$\frac{d\rho}{dp_T} = \frac{1}{N_{\text{ev}}} \times \frac{1}{\langle \text{Area} \rangle} \times \frac{dN}{dp_T}, \quad (1)$$

where N_{ev} is the number of events and $\langle \text{Area} \rangle$ is the averaged per event acceptance of V^0 s ($\Delta\eta \times \Delta\varphi$). The p_T -differential density of V^0 particles produced in jets is obtained by subtracting the underlying V^0 density from the V^0 s matched with jets. Feed-down of Λ from Ξ decays in jets is corrected using the feed-down fraction of inclusive Λ obtained from data. The systematic uncertainty of the fraction of feed-down of Λ in jets was estimated using the difference between the PYTHIA8 simulation and the inclusive measurements at high- p_T in the data. The uncertainty on jet background fluctuations is evaluated by varying the jet p_T threshold by 20%.

3. Results

Fig. 1 shows p_T -differential density of V^0 s produced in jets (red points) after the underlying background subtraction and feed-down correction in 0 – 10% (left) and 40 – 100% (right) event multiplicity classes. The results are obtained for charged particle jets with $R = 0.3$ and $p_{T,\text{jet}}^{\text{ch}} > 10$ GeV/c. A much harder spectrum is observed for the V^0 s produced in jets, relative to the inclusive V^0 s (black points).

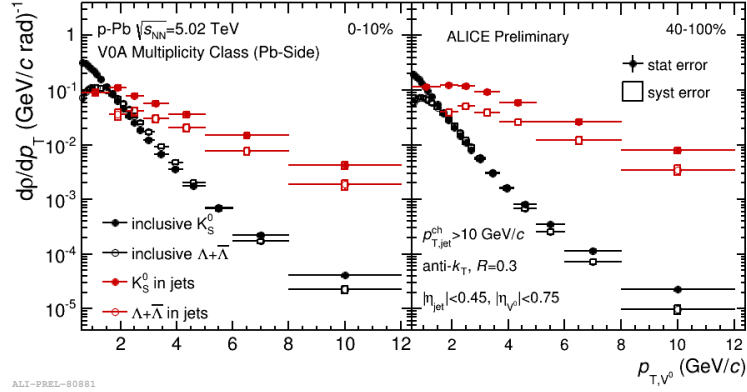


Figure 1. The p_T -differential density of K_S^0 and Λ ($\bar{\Lambda}$) in jets with $p_{T,jet}^{ch} > 10$ GeV/c in p–Pb collisions. Jets are reconstructed using charged particles and the anti- k_T algorithm with $R = 0.3$. Results are shown for two V0A multiplicity classes of p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV: 0 – 10% (left), and 40 – 100% (right). Results are compared to the inclusive V^0 p_T distribution.

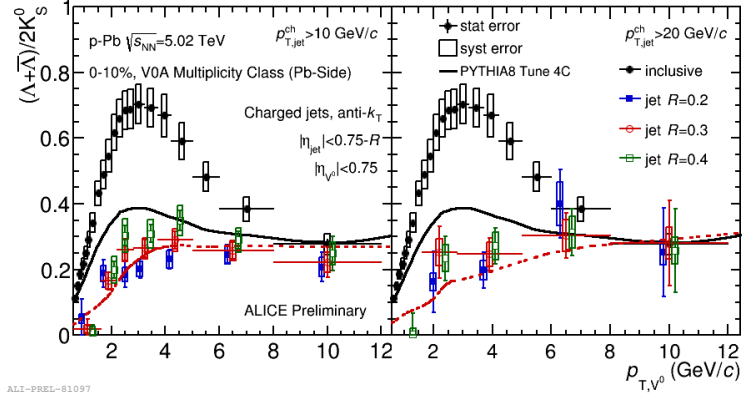


Figure 2. Λ/K_S^0 ratio in jets with $p_T^{jet} > 10$ GeV/c (left) and $p_T^{jet} > 20$ GeV/c (right) for events in the 0 – 10% V0A multiplicity class of p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Jets are reconstructed using charged particles and the anti- k_T algorithm. Results are shown for different jet R of 0.2, 0.3, and 0.4. The ratios in jets are compared to the inclusive distributions and the corresponding PYTHIA8 simulations (the pp collisions).

The Λ/K_S^0 ratios in jets with $R = 0.2$, 0.3 and 0.4 are presented in Fig. 2. The results are obtained in the 0 – 10% event multiplicity class with $p_{T,jet}^{ch} > 10$ GeV/c and > 20 GeV/c and compared to the inclusive V^0 in data and in PYTHIA8 [16] simulations. The ratios in jets do not depend on the jet radii and do not vary with $p_{T,jet}$. At the intermediate p_T ($2 < p_T < 4$ GeV/c) the inclusive ratio in p–Pb collisions is much larger than in PYTHIA8-generated pp collisions. This is consistent with previously reported baryon-to-meson enhancement in p–Pb collisions as compared to pp collisions [11]. On the other hand, the measured Λ/K_S^0 ratio in jets is significantly smaller than that of inclusive distribution. Moreover, it is compatible with the result of the analysis applied to the PYTHIA-generated pp collisions.

4. Conclusions

In contrast to the inclusive distribution, the Λ/K_S^0 ratio within jets in high-multiplicity p–Pb collisions does not exhibit baryon enhancement. The ratio in jets has similar magnitude and p_T dependence to the ratio in low-multiplicity p–Pb collisions, and to the inclusive ratio found in pp collisions. It is also consistent with the analysis performed on the pp collisions simulated with PYTHIA8 event generator. It is plausible that the baryon enhancement may therefore be attributable to the soft (low Q^2) component of the collision as discussed in [25]. This result disfavors

the hard-soft recombination models while it is consistent with a picture in which the value of baryon/meson ratio has two independent mechanisms: i) the expansion of the soft particles of the underlying event within a common velocity field (radial flow), and ii) the production of particles via hard parton–parton scatterings and the subsequent jet fragmentation.

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